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VESSEL FOR WELL INTERVENTION

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VESSEL FOR WELL INTERVENTION

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments of the present invention generally relate to an apparatus and method for intervening in offshore pipelines. Embodiments also relate to an apparatus and method for drilling and casing an offshore wellbore.

Description of the Related Art

[0002] Hydrocarbon production occurs either directly from the earth or from the earth below a body of water. Production directly from the earth is typically termed a "land production operation," while production from the earth below a body of water is ordinarily typically termed an "offshore production operation" or a "subsea" production operation." To obtain hydrocarbons in either a land production operation or an offshore production operation, casing is inserted into a drilled-out wellbore within the earth formation. Casing isolates the wellbore from the formation, preventing unwanted fluids such as water from flowing from the formation into the wellbore. The casing is perforated at an area of interest within the formation which contains the desired hydrocarbons, and the hydrocarbons flow from the area of interest to the surface of the earth formation to result in the production of the hydrocarbons. Typically, hydrocarbons flow to the surface of the formation through production tubing inserted into the cased wellbore.

[0003] Casing is inserted into the formation to form a cased wellbore by a well completion operation. In conventional well completion operations, the wellbore is formed to access hydrocarbon-bearing formations by the use of drilling. Drilling is accomplished by utilizing a cutting structure that is mounted on the end of a drill support member, commonly known as a drill string. To drill within the wellbore to a predetermined depth, the drill string is often rotated by a top drive or rotary table on a surface platform or rig, or by a downhole motor mounted towards the lower end of

the drill string. After drilling to a predetermined depth, the drill string and its cutting structure are removed from the wellbore and a section of casing is lowered into the wellbore. An annular area is thus formed between the string of casing and the formation. The casing string is temporarily hung from the surface of the well. A cementing operation is then conducted in order to fill the annular area with cement. Using apparatus known in the art, the casing string is cemented into the wellbore by circulating cement into the annular area defined between the outer wall of the casing and the borehole. The combination of cement and casing strengthens the wellbore and facilitates the isolation of certain areas of the formation behind the casing for the production of hydrocarbons.

[0004] It is common to employ more than one string of casing in a wellbore. In this respect, the well is drilled to a first designated depth with a cutting structure on a drill string. The drill string is removed. A first string of casing or conductor pipe is then run into the wellbore and set in the drilled out portion of the wellbore, and cement is circulated into the annulus behind the casing string. Next, the well is drilled to a second designated depth, and a second string of casing, or liner, is run into the drilled out portion of the wellbore. The second string is set at a depth such that the upper portion of the second string of casing overlaps the lower portion of the first string of casing. The second liner string is then fixed, or "hung" off of the existing casing by the use of slips which utilize slip members and cones to wedgingly fix the new string of liner in the wellbore. The second casing string is then cemented. This process is typically repeated with additional casing strings until the well has been drilled to total depth. In this manner, wells are typically formed with two or more strings of casing of an ever-decreasing diameter.

[0005] As an alternative to the conventional method, drilling with casing is a method often used to place casing strings of decreasing diameter within the wellbore. This method involves attaching a cutting structure in the form of a drill bit to the same string of casing which will line the wellbore. Rather than running a cutting structure on a drill string, the cutting structure or drill shoe is run in at the end of the casing that will remain in the wellbore and be cemented therein. Drilling with casing is often

the preferred method of well completion because only one run-in of the working string into the wellbore is necessary to form and line the wellbore per section of casing placed within the wellbore.

[0006] Drilling with casing is especially useful in drilling and lining a subsea wellbore in a deepwater well completion operation. When forming a subsea wellbore, the initial length of wellbore that has been drilled is subject to potential collapse due to soft formations present at the ocean floor. Additionally, sections of wellbore that intersect areas of high pressure can cause damage to the wellbore during the time lapse between the formation of the wellbore and the lining of the wellbore. Drilling with casing minimizes the time between the drilling of the wellbore and the lining of the wellbore, thus alleviating the above problems.

[0007] After production of the hydrocarbons at the surface of the earth formation, the hydrocarbons must be stored at a location and subsequently processed to remove undesired contaminants in the hydrocarbons and to produce the desired product. In land production operations, one option for storage and processing involves storing the hydrocarbons at a tank beside the wellbore, removing the hydrocarbons at time intervals from the storage unit with a mobile storage unit, physically transporting the hydrocarbons with the mobile storage unit to a processing unit, removing the hydrocarbons from the mobile storage unit and into the processing unit, and then processing the hydrocarbons at the processing unit.

[0008] Another option for storing and processing the hydrocarbons in land production operations includes using a pipeline connected to the production tubing. The hydrocarbons flow from the formation through the perforations, into the production tubing, through the pipeline, and into a storage and processing unit at a remote location. The storage and processing unit typically receives multiple pipelines from multiple land production operations at various wellbores to allow storage and processing of hydrocarbons from multiple locations at one facility without the need for physically transporting the hydrocarbons to the processing unit.

[0009] The above options for storage and processing of hydrocarbons produced during land production operations are feasible because of the unlimited space available for storage units and processing units on the land. Offshore production operations, however, require alternative storage and processing methods because of the limited space allotted to hydrocarbon production at the surface of a body of water. Thus, methods for storing large quantities of hydrocarbons at a remote location are currently practiced.

[0010] Offshore wells are often drilled and completed by use of a drilling rig. The drilling rig includes legs which rest on the floor of the body of water and support a rig floor. A hole is located in the rig floor of the drilling rig through which supplies for completing and drilling the wellbore, such as a drill string and casing strings, may be inserted and lowered into the body of water. The wellbore is typically drilled out by use of the drill string, then strings of casing are placed within the drilled-out wellbore to form a cased wellbore. Perforations are created in the casing and the formation as described above. A riser, which is piping which spans the distance of the water from the ocean floor to the surface of the water, is ultimately inserted at the top of the cased wellbore. Because drilling rigs are relatively expensive to maintain above the wellbore after the completion operation, the drilling rig is removed from its location above the completed wellbore and employed to drill a subsequent wellbore at a different location. At this point, production of the hydrocarbons and subsequent storage of the hydrocarbons becomes an issue.

[0011] One method for producing and storing hydrocarbons in offshore operations involves first building a production platform on the ocean floor. Like the drilling rig, the production platform includes a platform supported on legs which extend to the ocean floor. Production tubing is lowered from a hole which exists in the production platform into the riser and the cased wellbore to the area of interest which contains the perforations, then the hydrocarbons flow through the production tubing to a storage unit located on the production platform. The production platform is usually not large enough to accommodate the large volume of hydrocarbons which flow through the production tubing to the production platform; therefore, the

production platform must only store hydrocarbons until a tanker arrives to transport the hydrocarbons from the storage unit to a larger storage and processing unit at another location. This method is expensive because each production platform above each wellbore which must be constructed and maintained represents a relatively large expense.

[0012] Alternatively, a subsea well intervention vessel having processing equipment coupled to storage tanks and having well intervention equipment may be utilized to produce hydrocarbons through coiled tubing drilling or to store or process hydrocarbon mixtures produced from underbalanced drilling, as described in U.S. Publication Number 2003/0000740 published on January 2, 2003, filed by *Haynes et al.* and entitled "Subsea Well Intervention Vessel", which is herein incorporated by reference in its entirety. The intervention equipment is theoretically capable of reentering existing production wells without changing the wellbore from its production mode.

[0013] As a more economic alternative to installing a production platform above each wellbore, a second method of producing and storing hydrocarbons in an offshore operation is more often practiced. Rather than building and maintaining a production platform for each wellbore, the median step in the production and storage operation which includes the production platform is eliminated by satelliting. Satelliting involves installing pipelines at each wellbore and routing all of the pipelines to a common storage and processing location, typically termed a "satellite unit," through the pipelines. The pipelines remain underwater from the wellbore until reaching the storage and processing unit.

[0014] Special problems are currently encountered when satelliting. The hydrocarbons must often travel long distances through the underwater pipelines to reach the satellite unit. The water through which the hydrocarbons must pass is very low in temperature, especially at the ocean floor where the pipelines are commonly placed. Because of the cold temperatures within the water, flowing the liquid hydrocarbons underwater for long distances is often challenging. One

problem which may result from the cold temperature of the water involves the viscosity of the hydrocarbons. Viscosity of liquid hydrocarbons increases as the hydrocarbons decrease in temperature. The higher the viscosity of the hydrocarbon liquid, the lower the flow rate of the hydrocarbon liquid becomes. Therefore, the colder the water surrounding the pipelines becomes, the more difficult or impossible flowing the hydrocarbons from the wellbore to the storage unit becomes. Decreasing viscosity of the liquid hydrocarbons flowing in the pipeline may ultimately cause blockage within the pipeline, reducing or halting hydrocarbon production.

[0015] A second problem which may result from the cold temperature of the water involves the changing temperatures of the hydrocarbons during their production. Within the wellbore, temperatures are high, causing the hydrocarbons to possess a high temperature.. The hydrocarbons within the wellbore may contain both the liquid and gas phases. As described above, the environment within the water when the hydrocarbons travel through the pipelines consists of low temperatures. Then, when the hydrocarbons are flowed from the pipeline up to the satellite unit, the temperature of the environment of the hydrocarbons becomes increasingly higher as the temperature increases with decreasing depth within the water. These temperature variations when using pipeline to transport produced hydrocarbons to the satellite unit often result in precipitation of the hydrocarbons on the inside of the pipeline. Eventually, the precipitation build-up may result in partial or total blockage of the flow path through the pipeline, decreasing or stopping hydrocarbon production. Reduced hydrocarbon production decreases the profitability of the wellbore.

[0016] Other problems which require pipeline intervention to reduce blockage include paraffin deposits which often build up in the pipelines due to the presence and flow of oil, as well as gas hydration when gas is present in the hydrocarbon stream. Some form of pipeline intervention must occur to reduce blockage within the pipeline caused by cold and variable temperatures. Pipeline intervention may also be necessary to repair holes or tears in the pipeline caused by corrosion of the pipeline or holes, tears, or bends due to physical assault of the pipeline.

[0017] Currently, an intervention operation requires a remotely operated vehicle to raise the pipeline off the ocean floor, cut out the damaged section of pipe, install pipe connections on the cut ends of the pipeline, and then install and connect a new section of pipeline. Other intervention operations require stoppage of the flow of hydrocarbons through the pipeline to introduce treatment fluid into the pipeline to remove blockage within the pipeline. For the intervention process, to prevent hydrocarbons from escaping from the pipeline to the water, hydrocarbon flow must be halted during the intervention operation.

[0018] Pipeline intervention operations are costly. Because interventions require physical invasion of the interior of the pipeline, hydrocarbon flow must be halted to conduct an intervention. Stopping the flow of the hydrocarbons reduces the profitability of the well, as the equipment and labor required to produce the hydrocarbons is still funded while no hydrocarbon production is occurring to offset these costs. It is therefore desirable to allow hydrocarbon production during pipeline intervention operations in offshore wells.

[0019] Light intervention vessels are available which make it possible to conduct operations such as well servicing, e.g. well logging and general maintenance. Such vessels, however, cannot be considered appropriate platforms for interventions requiring drilling or hydrocarbon production as they are not sufficiently stable for such operations and are too small to handle the volumes of material that result from drilling. As such, the vessels must be supplemented with support vessels to receive produced hydrocarbons. Furthermore, light intervention vessels require large capital investments as compared with the returns that can be generated, particularly as they are highly vulnerable to bad weather such that intervention costs are relatively high and utilization time is relatively low. Even more cost is required to employ an additional support vessel. Because of the above disadvantages, no attempts have been made to use continuous casing to drill and line a wellbore from floating units or to allow hydrocarbon production during intervention operations in offshore wells.

[0020] Furthermore, while drilling with sections of casing minimizes the time between the drilling of the wellbore and the lining of the wellbore, it remains desirable to further minimize the time between the drilling and lining of the wellbore to decrease production costs and further prevent collapse of the formation during the time lapse. It is also desirable to provide an alternative to the costly drilling platform or the option of two vessels (one having the drilling equipment and one having storage equipment) by allowing drilling with casing completion operations as well as production operations to be conducted concurrently from the same structure.

SUMMARY OF THE INVENTION

[0021] In one aspect, the present invention provides a method and apparatus for intervening in a pipeline, comprising providing a pipeline for transporting fluid flow from an offshore well to a location, diverting the fluid flow to a storage site, and intervening in the pipeline. Diverting the fluid flow to the storage site may comprise diverting the fluid flow to an offshore tanker while intervening in the pipeline from the offshore tanker.

[0022] In another aspect, the present invention provides an apparatus for remediating an offshore pipeline and producing well fluids, comprising a vessel capable of storing well fluids flowing through the pipeline from a well, a first tubular body disposed within the vessel for diverting well fluid flow from the pipeline to the vessel for storing, and a second tubular body disposed within the vessel for remediating the pipeline. The vessel may be capable of diverting well fluid flow through the first tubular body while remediating the pipeline through the second tubular body and capable of remediating the pipeline without interruption of production of well fluids.

[0023] In yet another aspect, the present invention provides a method of drilling a subsea wellbore from a vessel, comprising locating the vessel, the vessel having continuous casing, drilling the wellbore, and casing the wellbore with the continuous casing. Drilling and casing the wellbore may comprise drilling the wellbore with the continuous casing.

[0024] In yet a further aspect, the present invention provides a vessel for drilling an offshore wellbore, comprising a positionable vessel, continuous casing having an earth removal member operatively attached thereto disposed on the vessel for drilling the wellbore, and storage equipment disposed on the vessel for storing hydrocarbon fluid produced from the wellbore. The vessel may further comprise processing equipment connected to the storage equipment for processing the hydrocarbon fluid produced from the wellbore.

[0025] The present invention advantageously allows offshore or subsea intervention operations to occur within a pipeline while simultaneously producing hydrocarbons from the pipeline, thus increasing profitability of the wellbore. Further, the present invention permits formation of an offshore or subsea cased wellbore with one run-in of the casing, and also allows for storage and/or processing of hydrocarbons during the drilling process on the same vessel which houses the equipment used to form the cased wellbore, increasing the profitability of the wellbore.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0027] Figure 1 is a sectional view of a satellite pipeline operation. A first tap is inserted into the pipeline for connection to a vessel at or near the surface of the water.

[0028] Figure 2 is a sectional view of the satellite pipeline operation of Figure 1, with a first tubular member lowered from the vessel and connected to the first tap to divert fluid flow from the pipeline to the vessel.

[0029] Figure 3 is a sectional view of the satellite pipeline operation of Figure 1, with a second tap inserted into the pipeline downstream from the first tap to remediate the pipeline.

[0030] Figure 4 is a sectional view of the satellite pipeline operation of Figure 1, with a second tubular member lowered from the vessel and connected to the second tap to remediate the pipeline.

[0031] Figure 5 is a sectional view of a drilling operation with continuous casing, where the drilling operation is performed from a vessel at or near the surface of the water. The continuous casing is poised above a hole in the floor of the vessel prior to drilling.

[0032] Figure 6 is a sectional view of the drilling operation of Figure 5, where the cutting structure operatively attached to the continuous casing drills through the ocean floor and into the formation to form a wellbore.

[0033] Figure 7 is a sectional view of the drilling operation of Figure 5, where the continuous casing is drilled into the formation to a desired depth. The continuous casing is severed at a location, and the cutting structure is retrieved from the wellbore.

[0034] Figure 8 is a side view of an embodiment of a vessel which may house and facilitate use of equipment for remediating a pipeline or drilling a wellbore.

[0035] Figure 9 is a schematic layout diagram of pipeline intervention equipment on the vessel of Figure 8.

[0036] Figure 10 is a schematic view of an alternate embodiment of a vessel which defines moon pools through which drilling or intervention may be performed.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0037] Figure 8 illustrates a vessel 10 embodying the present invention. Figure 8 is based on a drawing extracted from "First Olsen Tankers" and shows a shuttle

tanker of the type widely used in the North Sea. In the vessel 10, the only modification made to the standard shuttle tanker is the mounting of a superstructure 107 above the main deck (not shown) of the vessel 10, for example at a height of approximately 3 meters so as to exist above the installed deck pipes and vents (not shown). A standard North Sea specified shuttle tanker with dynamic positioning can be readily charted and fitted with a new deck above the installed deck pipes and vents, upon which deck can be installed, for example, the following equipment: a skid mounted derrick riser handling unit with subsea control panel; stumps for the subsea well intervention equipment; a pipe rack; coiled tubing reels, a control unit, and a power pack; a cementing unit and blender, production test equipment including a choke manifold, heater treater, separators, degassing boot and gas flare; tanks for kill mud; a closed circulation system for handling drilling mud and drilled solids during underbalanced drilling; storage tanks for chemical and solid wastes; cranes for subsea equipment and supplies; remote controlled vehicles for working and observation tasks; and water supplies for cooling and fire fighting services (see below). All the equipment necessary for pipeline intervention and/or drilling is mounted on the superstructure 107, including a crane 108. The detailed layout of the equipment mounted on the superstructure 107 of Figure 8 is shown in Figure 9.

[0038] Referring to Figure 9, a skid deck 109 is centrally mounted on the superstructure 107 adjacent a gantry crane 110. On the other side of the gantry crane 110 is a riser deck and laydown area 335. Between the crane 108 and the skid deck 109 are a subsea laydown area and equipment stumps 340, remotely operated vehicles 341, and a subsea control unit 342. Also located on the superstructure 107 are a gas compressor 343, air compressor 344, and firewater pumps 345. Coiled tubing drilling equipment 111 of conventional form (described below) is mounted adjacent the gantry crane 110, including but not limited to a laydown area, power pack, control unit, goose neck, injector head, conveyor, reels, and blowout preventors. A slickline contractor 302 and an electric line contractor 301 may be disposed by the coiled tubing drilling equipment 111. A separator assembly 112 and ancillary drilling support equipment assembly 106 are also mounted on the superstructure 107. The separator assembly 112 may include, but

is not limited to, separators 310A-D, chokes 311, a heater treater 312, a cuttings treatment unit 313, mud cleaning unit 314, produced water cleaning unit 315, metering gas oil unit 316, and chemical injection unit 317. The ancillary drilling support equipment assembly 106 may include but is not limited to kill mud unit 320, completion fluid unit 321, active mud tanks 322 and 323, hexanol (HeOH) unit 324, spare unit 325, waste unit 326, cuttings waste unit 327, mud pumps 328, and cement unit 329. Between the drilling support equipment assembly 106 and the separator assembly 112 are a process control unit 330 and a laboratory 331. All other equipment relied upon to achieve the required direct well intervention is also mounted on the superstructure 107. The separator assembly 112 is connected to an appropriately positioned flare stack (not shown), for example at the stern (not shown) of the vessel 10 and to the storage tanks (not shown) of the vessel 10 so as to enable produced hydrocarbon fluids to be stored for subsequent transport.

[0039] In use, the vessel 10 is dynamically positioned above a subsea well or pipeline. The skid deck 109 is then moved to an outboard position (not shown) over the subsea well or the pipeline to enable the coiled tubing equipment 111 to be coupled to a riser above the subsea well for drilling or to a tap 80 or 90 (see Figures 1-4) installed within the pipeline 20. Appropriate interventions can then be made via the tubular member or coiled tubing drilling can be conducted in a manner which produces a multiphase mixture of the hydrocarbon fluid that is subsequently separated into its different phases in the separator assembly 112.

[0040] Figure 10 shows an alternate arrangement of the vessel 10 for mounting equipment for use with the present invention. As an alternative to providing a skid deck displaceable to an outboard position, as shown in Figures 8-9, the drilling and/or intervention equipment could be mounted adjacent a moon pool 113 or 114 extending through the deck of the vessel 10. Particularly, the components are mounted adjacent moon pools 113 and 114 extending vertically through the structure of the vessel 10. Three cranes 115, 116, and 117 can extend over the moon pools 113 and 114 and areas indicating cargo manifolds 118, a derrick module 119, and a lay down area 120. Area 121 houses gas compression and

process units, area 122 a flare boom, area 123 a flare knock-out drum skid, and area 124 a further lay down area served by a crane 125.

[0041] When employing a standard double hull shuttle tanker, the modifications required to produce the vessel 10 illustrated in Figure 10 which can function in accordance with the present invention would include an upgrade of the dynamic positioning capability, installation of a first moon pool for intervention and/or drilling work, installation of a second moon pool for remotely operated vehicle work, mounting of cranes, process equipment and lay down areas for deck-mounted equipment, and the mounting of flare facilities and associated utilities.

[0042] Figures 1-4 show the vessel 10 of the present invention, which is capable of diverting flow from a pipeline 20 and/or remediating the pipeline 20 during a satellite pipeline operation. A superstructure 215 mounted on legs 216 exists on the vessel 10 and has a hole 218 therein for lowering intervention equipment therethrough. The vessel 10, in the embodiment shown, includes a hole 213 in its floor essentially in line with the hole 218 for lowering intervention equipment therethrough. Referring to Figure 1, in the satellite pipeline operation, the pipeline 20 is located at or near the floor 30 of a body of water 40. The pipeline 20 initially transports well fluid 45, typically hydrocarbon fluid, from a wellbore 50 disposed in the floor 30 to a satellite storage unit 55 disposed at least partially above a surface 60 of the body of water 40.

[0043] The wellbore 50 is drilled into the floor 30 to a depth at which well fluid 45 exists. The wellbore 50 may be completed with casing 51, as shown in Figures 1-4, or may remain an open hole wellbore with no casing disposed therein. The pipeline 20 is connected to production tubing 52. The production tubing 52 is located within the wellbore 50 and extends at least to an area of interest (not shown) in the floor 30, which is a depth at which the well fluid 45 exists. The production tubing 52 typically includes packing elements (not shown) disposed around its outer diameter which extend to the wellbore 50 above and below the area of interest in the floor 30 to isolate the area of interest within the wellbore 50. Perforations (not shown) are

inserted into the production tubing 52 across from the area of interest in the wellbore 50, and perforations (not shown) are likewise inserted into the area of interest in the wellbore 50. Well fluid 45 thus flows from the area of interest in the wellbore 50 into an annular area 53 between the outer diameter of the production tubing 52 and the wellbore 50, then up through the production tubing 52 disposed within the wellbore 50 and into the pipeline 20.

[0044] The satellite storage unit 55 is capable of storing well fluid 45 received from the pipeline 20. The satellite storage unit 55 may also possess well fluid processing capabilities. In addition to storing and/or processing well fluid 45 from the pipeline 20, the satellite storage unit 55 may also receive well fluid 60 from any number of additional pipelines 65. Each additional pipeline 65 is connected to production tubing (not shown) inserted within a wellbore (not shown), as described above in relation to production tubing 52 within the wellbore 50, at a different location within the floor 30 than the wellbore 50.

[0045] In Figure 1, a problem area 70 exists in the pipeline 20 which must be treated in some manner to resume the desired well fluid 45 flow through the pipeline 20. The problem area 70 may include, but is not limited to, partial or total blockage of flow in the pipeline 20 due to precipitation build-up on the inside of the pipeline 20 which must be removed from the pipeline 20, paraffin deposits on the inside of the pipeline 20 which must be descaled or removed, or gas hydration within the pipeline 20. The problem area 70 may also include bends, holes, or corrosion damage to the pipeline 20 which must be repaired. Additionally, the problem area 70 may include stuck equipment which must be dislodged from within the pipeline such as a stuck pig.

[0046] Because the problem area 70 disrupts the desired flow of the well fluid 45, an intervention or remediation of the pipeline 20 must be performed. The intervention may include dislodging stuck equipment, removing build-up or deposits in the pipeline 20 causing partial or total blockage of the pipeline 20, and/or repairing damage to the pipeline 20. In all of the above intervention situations, the pipeline 20

must be physically invaded in some fashion to fix the problem area 20 and restore ordinary fluid flow 45 from the wellbore 50 to the satellite storage unit 55.

[0047] The vessel 10 or tanker of the present invention is employed to fix the problem area 20. The vessel 10 may be disposed on the surface 60 of the water 40, partially below the surface 60, or completely below the surface 60. Within the vessel 10 is a second tubular body 12, preferably coiled tubing. A first tubular body 11, also preferably coiled tubing, extends from the vessel 10 into the water 40. The first tubular body 11 may be inserted into a riser pipe (not shown) which extends from the vessel 10 to the floor 30. At an upper end, the first tubular body 11 is sealably connected to a storage tank 13 for storing produced well fluid 45 from the wellbore 50, which may be connected to a processing unit (not shown) on the vessel 10 for processing well fluid 45. The processing unit may include liquid separation equipment. The first tubular body 11 may comprise three tubular sections, including 11A, 11B, and 11C. At its lower end, tubular section 11A is connected, preferably threadedly connected, to an upper end of tubular section 11B. Tubular section 11B is a portion of a blow out preventer 9. The blow out preventer 9 includes a large valve 8 which may be closed to control well fluids 45. The valve 8 is typically closed remotely through hydraulic actuators (not shown). Tubular section 11B is connected, preferably threadedly connected, at its lower end to an upper end of tubular section 11C.

[0048] Connected to the pipeline 20 in Figure 1 is a first tap 80 which is capable of fluid communication with the pipeline 20 through a first hole 84 in the pipeline 20. The first tap 80 is a tubular body having a valve 81 disposed therein for selective disruption of fluid flow through the tubular body. The first tap 80 is connected to the pipeline 20 through a first clamp 82 disposed around the pipeline 20 and is held in sealing engagement with the pipeline 20 due to sealing members 83A, 83B, 83C, and 83D. Any number of sealing members 83A-D may be employed to secure sealed fluid communication between the first tap 80 and the pipeline 20.

[0049] Referring now to Figure 3, a second tap 90 is installed in the pipeline 20 between the problem area 70 and the first tap 80. The second tap 90 is a tubular body with a second valve 91 therein to selectively obstruct fluid flow through the tubular body. A second clamp 92 is sealably disposed around the pipeline 20 by sealing members 93A-D to provide sealed fluid communication between the second tap 90 and the pipeline 20 through a second hole 94 in the pipeline 20.

[0050] In operation, the wellbore 50 is drilled into the floor 30 and lined with casing 51, and the pipeline 20 is connected at one end to production tubing 52 within the wellbore 50 and at the opposite end to the satellite storage unit 55. Fluid flow 45 continues essentially uninhibited through the pipeline 20 from the area of interest in the wellbore 50 to the satellite storage unit 55 until a problem area 70 develops in the pipeline. The vessel 10 is located above the pipeline 20 near the problem area 70 to conduct a pipeline intervention operation and remove or repair the problem area 70.

[0051] Once the vessel 10 is positioned above the pipeline 20 near the problem area 70, a first tap 80, with the first valve 81 in the closed position, is installed into the pipeline 20 between the problem area 70 and the wellbore 50. To install the first tap 80, a cutting tool (not shown) such as a milling tool, which is known to those skilled in the art, may be utilized to drill the first hole 84 in the pipeline 20. The first clamp 82 is opened and positioned around the pipeline 20 at the desired point of insertion of the first tap 80. The sealing members 83A-D disposed between the first clamp 82 and the pipeline 20 are used to produce and maintain a fluid-tight sealed connection between the first tap 80 and the pipeline 20. After installation of the first tap 80, the first tubular member 11 is lowered from the vessel 10 through the hole 113 in the floor of the vessel 10, which may be the skid deck 109 in the outboard position of Figures 8-9 or the moon pool 113 or 114 of Figure 10, depending upon the configuration of the vessel 10 which is used.

[0052] Next, the lower end of the first tubular member 11 is connected, preferably threadedly connected, to the upper end of the first tap 80. The first valve 81 is then

opened to allow well fluid 45 to flow along a sealed path from the perforations in the wellbore 50 into the production tubing 52 through the perforations in the production tubing 52, and into the pipeline 20. Then the fluid flow 45 is diverted from further flow through the pipeline 20 to flow up through first tap 80 and the first tubular member 11 into the storage tank 13. From the storage tank 13, the well fluid 45 may be diverted to the processing unit which may exist on the vessel 10, or, in the alternative, may eventually be transported to another facility for processing. Figure 2 shows production of the well fluid 45 diverted through the first tap 80 to the vessel 10 for storage and/or processing.

[0053] Once well fluid 45 flow is effectively diverted to the vessel 10, the intervention may be accomplished without interruption of the production of the well fluid 45. External patching or bending of the problem area 70 may be conducted without the installation of the additional second tap 90 if the problem area 70 is a hole or bend. If it is desired to intervene into the pipeline 20 by introduction of an object (not shown) or a treatment fluid 21 (see Figure 4) into the pipeline 20, the second tap 90 may be installed on the pipeline 20 between the problem area 70 and the first tap 80.

[0054] Installation of the second tap 90 proceeds much as the installation of the first tap 80. Again, the second valve 91 is in the closed position during the installation of the second tap 90. The cutting tool (not shown) such as the milling tool may be utilized to drill the second hole 94 in the pipeline 20. If it is desired to install the second tap 90 (or the first tap 80) at an angle with respect to the pipeline 20, a whipstock (not shown) may be used to guide the cutting tool (e.g., mill) into the pipeline 20 at an angle, as is known in relation to drilling deviated wellbores from parent wellbores. The second clamp 92 is then opened and positioned around the pipeline 20 at the desired point of insertion of the second tap 90. The sealing members 93A-D disposed between the second clamp 92 and the pipeline 20 are used to produce and maintain a fluid-tight sealed connection between the second tap 90 and the pipeline 20. Figure 3 shows the second tap 90 installed at the

pipeline 20 between the problem area 70 and the first tap 80, with the second valve 91 in the closed position.

[0055] After the second tap 90 is installed on the pipeline 20, the lower end of the second tubular body 12 is connected, preferably threadedly connected, to an upper end of the second tap 90. The second valve 91 is then opened to allow fluid communication between the vessel 10 and the pipeline 20. If it is desired to introduce an object into the second tubular body 12, then the object may be directly introduced into the upper end of the second tubular body 12. If, as is shown in Figure 4, it is desired to introduce treatment fluid 21 into the pipeline 20 to dislodge, disband, or dissolve partial or total blockage existing in the problem area 70, a storage tank 22 with the treatment fluid 21 housed therein is connected to the upper end of the second tubular body 12. As shown in Figure 4, the treatment fluid 21 is then introduced into the second tubular body 12 to flow through the second tap 90 and into the pipeline 20 toward the problem area 70. The treatment fluid 21 may be separated from the well fluids present at the satellite storage unit 55 until the pipeline 20 flow between the wellbore 50 to the satellite storage unit 55 is restored. Figure 4 shows the intervention operation conducted through the second tap 90 and the pipeline 20 while production of the well fluid 45 continues uninterrupted from the wellbore 50, through the first tap 80, and into the vessel 10.

[0056] The pipeline intervention operation is conducted until the problem area 70 is effectively treated and no longer a threat to production of the well fluid 45. Upon completion of the pipeline intervention operation, the treatment fluid 21 flow is halted so that treatment fluid 21 is no longer introduced into the second tubular body 12 from the vessel 10. The second valve 91 is then closed and the second tubular body 12 disconnected from the second tap 90. Next, the first valve 81 is closed and the first tubular member 11 disconnected from the first tap 80. The first tubular member 11 as well as the second tubular member 12 is then retrieved to the vessel 10.

[0057] Upon closing of the second valve 91 and the first valve 81, the resumed well fluid 45 flow through the pipeline 20 is ultimately essentially unaffected by the pipeline intervention operation. Closing the valves 91, 81 obstructs the alternate paths for the well fluid 45 flow which existed during the intervention operation. Well fluid 45 may again flow from the wellbore 50 through the production tubing 52, into the pipeline 20, through the former problem area 70, and up into the satellite storage unit 55 for storage and/or processing. Advantageously, the production of well fluid 45 was accomplished either into the storage tank 13 or into the satellite storage unit 55 without interruption through the present invention.

[0058] It is understood that the above intervention method and apparatus may be utilized not only in repairing a problem area 70 in the pipeline 20, but also in installing and retrieving subsea equipment. The alternate route through the first tap 80 and the first tubular member 11 may be utilized to divert well fluid 45 flow while installing or retrieving equipment within the water 40 when the installing or retrieving involves physical invasion of the pipeline 20.

[0059] In another embodiment of the present invention, the vessel 10 may be utilized to drill into a formation 201 within the floor 30 of the body of water 40 using continuous casing 210. Figures 5-7 show the embodiment of the vessel 10 which is depicted in Figure 10, as the moon pool 113 is located in the bottom of the vessel 10. In the alternative, it is contemplated that the skid deck 109 arrangement of Figures 8-9 may also be utilized to communicate the continuous casing 210 into the formation 201 from the vessel 10.

[0060] Referring to Figure 5, the vessel 10 has a superstructure 215 disposed thereon, which is supported above the vessel floor 217 by legs 216. A hole 218 is disposed in the superstructure 215 above the moon pool 113 and substantially in axial line with the moon pool 113. Equipment utilized in the drilling process is lowered through the hole 218 in the superstructure 215 and the moon pool 113 at various stages of the operation.

[0061] A riser pipe 221 extends from the moon pool 113 to the ocean floor 30. The riser pipe 221 provides a path through the body of water 40 to the floor 30 through which the continuous casing 210 may be lowered.

[0062] The continuous casing 210 is located on the superstructure 215 on a reel 225. A drilling fluid source 226 is in fluid communication at some location with the continuous casing 210 to provide drilling fluid to the continuous casing 210 at various stages of the drilling operation. A spider 227 or other gripping apparatus having gripping members such as slips (not shown) is also disposed on the superstructure 215 around or within the hole 218 to act as a back-up gripping device during the drilling operation for the continuous casing 210.

[0063] Also located on the superstructure 215 is equipment which is utilized to lower as well as retrieve the continuous casing 210 to and from the reel 225 as desired during the drilling operation. To this end, an injector head 230 is disposed on the superstructure 215. The injector head 230 includes conveying members 232 and 233, which are substantially centered around the hole 218 and suspended above the hole 218 by supports 234 and 235. The conveying members 232 and 233 of the injector head 230 act essentially as conveyor belts and are moveable clockwise and counterclockwise around the axis of the conveying members 232 and 233 to lower or retrieve the continuous casing 210 into or out from the hole 218. Also utilized to lower and retrieve the continuous casing 210 is a conveyor belt 240 on a track 241. The conveyor belt 240 on the track 241 is located between the reel 225 and the injector head 230 to obtain the continuous casing 210 from the reel 225 and feed the continuous casing 210 into the injector head 230, or to return the continuous casing 210 to the reel 225 from the injector head 230. The injector head 230 and the conveyor belt 240 on the track 241, as described above, are known to those skilled in the art as a method of feeding continuous tubing. Other aspects of the method of feeding continuous tubing or continuous casing to drill a wellbore known to those skilled in the art are contemplated for use with the present invention.

[0064] The continuous casing 210 includes a mud motor 245 disposed therein connected by a releasable connection 246 to the inner diameter of the continuous casing 210. An expandable cutting structure 250 with perforations 260 therethrough for circulating drilling fluid and/or setting fluid is attached to the mud motor 245. The expandable cutting structure 250 includes a body (not shown) and a blade assembly (not shown) disposed on the body, as is disclosed in co-pending U.S. Patent Application Serial Number 10/335,957 filed on December 31, 2002, which is herein incorporated by reference in its entirety. As disclosed in the above-referenced application, the blade assembly is movable between a closed position whereby the expandable cutting structure 250 has a smaller outer diameter and an open position whereby the expandable cutting structure 250 has a larger outer diameter. The blade assembly may be moveable between the open position and the closed position through a hydraulic pressure differential created across nozzles (not shown) within the expandable cutting structure 250. The expandable cutting structure 250 may further include a release assembly for providing a secondary means to move the blade assembly from the open position to the closed position, as disclosed in the above-referenced application.

[0065] The mud motor 245 may include a shaft (not shown) and a motor operating system (not shown). The mud motor 245, which is the mechanism for rotating the cutting structure 250, is hollow to allow for fluid flow therethrough at various stages of the drilling operation and is preferably a hydraulic mud motor operated by fluids pumped therethrough. The motor operating system turns the shaft, which rotates the expandable cutting structure 250 for drilling into the formation 201. The described mud motor 245 is not the only mud motor available for use with the present invention, as other types of mud motors which are known to those skilled in the art are contemplated for use with the present invention.

[0066] In addition to the equipment for drilling with continuous casing 210 described above, the vessel 10 may include hydrocarbon fluid separation equipment (not shown) coupled to one or more storage units (not shown) to receive separated hydrocarbon fluids from the wellbore 270. With the addition of storage capacity, the

vessel can collect produced hydrocarbon fluid during drilling with the continuous casing 210, thus eliminating the need for a separate vessel in the event that hydrocarbon fluid is produced during drilling.

[0067] In operation, referring to Figure 5, the vessel 10 is located above the floor 30 of the body of water 40, at or near the surface 60 of the body of water 40, so that the hole 218 in the superstructure 215 and the moon pool 113 are substantially aligned with the location at which it is desired to drill into the formation 201. The riser pipe 221 is lowered through the moon pool 113 to connect the vessel floor 217 to the floor 30 of the body of water 40 so that the continuous casing 210 and/or other tools may be lowered into the formation 201 without the interference of the body of water 40 in the drilling process. The continuous casing 210 is then pulled from the reel 225 onto the conveyor belt 240, and the conveyor belt 240 moves counterclockwise along the track 241 to feed the continuous casing 210 into the injector head 230 between the conveying members 232 and 233. The expandable cutting structure 250 is retracted at this point in the operation. The gripping members of the spider 227 are unactivated. Figure 5 illustrates this stage in the drilling operation.

[0068] Next, the continuous casing 210 is lowered through the hole 218 in the superstructure 215, through the moon pool 113, and through the riser pipe 221. Before the continuous casing 210 reaches the floor 30, the expandable cutting structure 250 is expanded, preferably due to hydraulic pressure. The continuous casing 210 is then lowered into the formation 201 while the mud motor 245 imparts torque to the cutting structure 250, thereby drilling a wellbore 270. While the expandable cutting structure 250 is drilling into the formation 201, drilling fluid is circulated from the drilling fluid source 226 into the continuous casing 210, then into the mud motor 245, through the perforations 260 in the expandable cutting structure 250, up through an annulus 275 between the continuous casing 210 and the wellbore 270, up through an annulus 280 between the continuous casing 210 and the riser pipe 221, and up to the vessel 10 for storage or recirculation. The fluid is circulated to carry cuttings and/or debris from the formation 201, which are produced

to the surface during drilling, and to facilitate a path for the drilling of the continuous casing 210 into the formation 201. Figure 6 shows the continuous casing 210 drilling into the formation 201.

[0069] The continuous casing 210 is drilled to the desired depth within the formation 201. At this point in the operation, setting fluid is introduced into the continuous casing 210 and circulated into the annulus 275 to set the continuous casing 210 within the wellbore. The expandable cutting structure 250 is then retracted to allow it to fit through the continuous casing 210, and a cutting tool (not shown) is utilized to sever the continuous casing 210 at the floor 30. The conveyor 240 may be manipulated to move clockwise around the track 241 to return the cut-off portion of the continuous casing 210 residing above the floor 30 to the reel 225.

[0070] To retrieve the mud motor 245 and the retracted expandable cutting structure 250 from the continuous casing 210, a wireline 290 is lowered from the superstructure 215. The wireline 290 is manipulated into a slot 291 located within the mud motor 245 and then pulled upward, pushed downward, or turned (when the releasable connection 246 is a threadable connection) to release the releasable connection 246, which is preferably a shearable connection which is sheared by pulling upward or pushing downward on the wireline 290. Releasing the releasable connection 246 allows the mud motor 245 and expandable cutting structure 250 to be moveable with respect to the continuous casing 210. Figure 7 shows the wireline 290 retrieving the expandable cutting structure 250 and the mud motor 245 from within the continuous casing 210. The wireline 290 is pulled through the moon pool 113 to the vessel 10 along with the expandable cutting structure 250 and the mud motor 245. Any other apparatus and method for retrieving the mud motor 245 and the cutting structure 250 known by those skilled in the art may be utilized with the present invention.

[0071] The drilling method of Figures 5-7 and the vessel 10 which is used to accomplish the drilling advantageously allow the wellbore 270 to be drilled into the formation 201 with one run-in of the continuous casing 210. The wellbore 270 is

now ready for subsequent operations such as hydrocarbon production operations. The same vessel 10 which was used for continuous casing 210 drilling described in Figures 5-7 may also be utilized for intervention operations described in Figures 1-4 if a pipeline 20 is used to produce fluids 45 from the wellbore 270 to the satellite storage unit 55.

[0072] The drilling method of Figures 5-7 is especially useful when employing the vessel 10 when drilling an offshore wellbore 270 in an underbalanced condition. Drilling in an underbalanced condition involves maintaining a positive pressure at the surface of the wellbore 270. Underbalanced drilling avoids damage to the wellbore 270 which can result from overbalanced drilling conditions when the drilling fluids invade the formation 201. Underbalanced drilling allows more efficient and faster hydrocarbon production from the formation 201. Because underbalanced wells produce significant volumes of hydrocarbons, the smaller remotely operated vehicles available are insufficient to store the produced fluids. The vessel 10 is capable of storing the volumes of fluid produced during underbalanced drilling. Furthermore, when drilling in an underbalanced state, the produced hydrocarbon fluid is a multiphase mixture of gas, solids, and liquids requiring separation. The drilling method of Figures 5-7 allows the capabilities of drilling with continuous casing 210, producing the hydrocarbons, storing the hydrocarbons with the storage equipment, and separating the produced multiphase mixture with the separating equipment using the same vessel 10. For a more detailed description of underbalanced drilling and the problems, especially problems with the resulting multiphase mixture, encountered when drilling underbalanced, refer to U.S. Patent Application Number 10/192,784, entitled "Closed Loop Multiphase Underbalanced Drilling Process", filed on July 10, 2002 by *Chitty et al.*, which is incorporated by reference in its entirety herein.

[0073] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.